NASA TECH BRIEF

Cryogenic Fluid Flow Instabilities in Heat Exchangers

An analytical and experimental investigation was conducted to determine the nature of oscillations and instabilities that occur in the flow of two-phase cryogenic fluids at both subcritical and supercritical pressures in heat exchangers. The objective was to obtain a fundamental understanding of the phenomena, without regard to the design parameters of a particular heat exchanger configuration.

The major experimental work was conducted with liquid nitrogen at subcritical pressures in an apparatus designed to provide data on the nature and rate of fluid (liquid and vapor) flow, heat transfer rates, and pressure drops. The heated test section of the apparatus was constructed of glass tubing to permit visual observation of the flow. This section was designed for very high heat fluxes, possibly the highest heat fluxes which had previously been attained in any other similar transparent heated section. Heat was generated by passing an electric current through a conductive coating on the inside walls of the tubing. Seven separate lengths of glass tubing were used in the heated test section, so that the electrical power input could be varied in each of the seven lengths independently. The high heat fluxes ensured complete vaporization of the liquid in a single pass through the heated section. Various modes of coupling the heated section to the rest of the apparatus could be selected.

The following four flow regimes were visually observed in the tests: liquid jet flow, bubbly flow, annular flow, and fog flow. It was found that the stability of the system depended both on the sequence in which these flows occurred along the heated tube and on the mode of coupling the liquid supply tank to the heated test section. In all cases, the highest amplitudes of flow oscillations occurred when the exit vapor quality (i.e., ratio of vapor mass flow rate to total fluid mass flow rate) was the highest. It is believed that this effect is due to the flow regimes which existed under conditions of relatively high heat fluxes required for high exit vapor quality. Visual and photographic observation indicated that in most tests with inlet subcooling, the area of wetted wall at the inlet remained fairly constant, even during oscillations. However, during oscillations, the flow regime in this inlet region changed periodically from bubbly, with clear liquid, to a churned-up mixture of liquid and vapor; and fog pulses at the same frequency as flow oscillations appeared at the tube outlet. The results of the tests with varying system parameters suggest certain design approaches with regard to heat exchanger geometry which should increase system stability.

Note:

Requests for further information may be directed to:
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Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

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